SPEECH INTELLIGIBILITY DURING EXERCISE AT NORMAL AND INCREASED ATMOSPHERIC PRESSURES

by

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NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 700

Bureau of Medicine and Surgery, Navy Department
Research Work Unit M4306.03-2020DAC5.08

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SUMMARY PAGE

THE PROBLEM

To evaluate changes in speech intelligibility as a result of exercise at normal and increased ambient pressures.

FINDINGS

The results indicate that at rest, speech intelligibility decreases by approximately 20 percent from surface to a depth equivalent to 150 feet of sea water. With the addition of a moderate exercise load, there is an additional drop in intelligibility; however, decreases in intelligibility do not continue as exercise loads increase.

APPLICATION

The information in this report indicates that to a certain extent, speech intelligibility under pressure is affected by an exercise task. It would appear from this information that speech tasks need to be evaluated as part of the ongoing mission of the dive in order to better understand the degree and type of activities which interfere with adequate voice communication.

This report should alert diving and hyperbaric personnel to the fact that intelligibility may vary depending upon the type of dive and the condition of the diver.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit M4306.03-2020DAC5, Evaluation of Underwater Communication Systems for Navy Divers. The present report is No. 8 on this work unit. It was approved for publication on 9 Feb. 1972 and designated as NAVSUBMEDRSCHLAB Report No. 700.

Capt. Edward W. Swenson, MC, USNR participated in this investigation as part of his active duty in the U.S. Naval Reserve.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL CENTER

ABSTRACT

The purpose of this study was to assess the effects of work loads at increased atmospheric pressures on speech intelligibility. Six subjects were exposed to depths equivalent to 0, 50, 100 and 150 feet of sea water. At each depth, the subjects recorded one 25 word PB list at each of four work loads 0, 50, 100 and 150 watts. Subjects were exercised on an ergometer and pedalling was maintained at the desired work load by monitoring a preset metronome. Heart rate and respiratory rate were monitored continuously using EKG electrodes and a nasal thermister. The speech signals were recorded with a microphone attached to a headband thus maintaining mouth-to-microphone distance constant. The recordings were played to naive listening panels to obtain speech intelligibility scores. The results indicate that at rest, speech intelligibility decreases by approximately 20 percent from surface to 150 feet. With the addition of a work load, there is an additional drop in intelligibility; however, intelligibility does not continue to decrease as work load increases.

SPEECH INTELLIGIBILITY DURING EXERCISE AT NORMAL AND INCREASED ATMOSPHERIC PRESSURES

INTRODUCTION

Previous data on the speech intelligibility of Navy divers and swimmers has been obtained from many talkers at various depths and in various gas mixtures. The existing data obtained during communication testing periods or free periods during dives has provided an index of the degree of intelligibility possible given certain test conditions including the diver's undivided attention to recording word lists, accurate monitoring of his voice level and in some cases, training in speech-reading methods. This study sought to extend intelligibility information to the working diver and to determine speech intelligibility levels when a diver is performing a physical task. From results of a previous investigation of speech during exercise in normal atmospheric pressure[1], alterations in both the rate of speaking and the intensity of speaking were observed; however, no attempt was made to assess the intelligibility of the speech samples. Since both of these factors contribute to overall intelligibility[2], it would appear that divers' speech would undergo changes in intelligibility while performing physical tasks during a diving mission. Our specific task was to assess the effects of exercise on speech intelligibility at the surface and at increased ambient pressures.

PROCEDURE

In order to determine the effects of exercise on speech intelligibility, six subjects recorded word lists while pedalling a bicycle ergometer at a prescribed exercise power level. Heart rate and respiratory rate were recorded after two minutes of pedalling at each power load applied to the ergometer. The subjects recorded one word list at each power load; this same procedure was followed until a different list was read at each of four power loads.

A Fleisch Universal Ergostat was used as the exercise unit. The ergostat was equipped so that the power needed to operate it could be increased in watt levels by increasing the resistance when a constant speed of pedalling was maintained. The subjects were trained to govern their exercise rate by pedalling in time with the beats of a metronome. The subjects always pedalled at a rate of 60 revolutions per minute.

Heart rate was monitored by recording the subjects' EKG's on a Beckman RS Dynograph Recorder. Respiratory rate was obtained by placing a nasal thermister near the nasal port and feeding the signal to a second channel of the Beckman recorder. Heart rate and respiratory rate were recorded at the start of each depth condition, before and after the reading of each word list, and at one, two, and five-minute intervals during the recovery period. The heart rate and respiratory rate obtained before and after each word list were averaged for each subject to obtain the values used in this study.

The speech material was recorded on an Ampex PR-10 tape recorder which was fed by a General Radio P-5 ceramic microphone. The microphone was worn on a metal headband which kept the mouth-to-microphone distance constant. Each subject recorded one Campbell PB-25 word list at each excerise load. The word lists were randomized so that subjects read one random order of a different list at each load for a particular depth. Thus, for each depth and power load, all of the lists used appeared an equal number of times.

TASKS

After the EKG electrodes, the nasal thermister, and the microphone headband were positioned on the subject, measures of the heart rate and respiratory rate were obtained while the subject was sitting at rest on the ergostat. The subject then recorded a PB-25 word list after which he immediately began pedalling at the fifty watt power load for two minutes. At the end of two minutes, heart rate and respiratory rate were again measured while the subject continued to exercise. The second word list was begun while exercising at the fifty watt power load, and upon completion of the list, heart rate and respiratory rate were measured. The power load was increased to 100 watts and exercise continued at this level for two minutes. The entire series was completed after the subject recorded his fourth word list, at which time he was pedalling at the 150 watt power load. Upon completion of the fourth list at a particular depth, vital signs were again recorded. Exercise was then stopped; heart rate and respiratory rate were monitored for five minutes while the subject rested. Thus, word lists were recorded at four power levels: 0, 50, 100, and 150 watts; and four depth conditions: surface, 50, 100, and 150 feet of equivalent sea water. No subject carried out more than one depth sequence in one day; in addition, the recordings were used only if a complete exercise sequence was carried out at one depth. The depth conditions were randomized for each subject in order to balance any familiarization or training effect associated with repetition of this type of task. The chamber was maintained at temperature of 73 degrees Fahrenheit plus or minus two degrees by venting for two minutes at five-minute intervals. The ventilation system was always secured prior to the recording.

The tape recordings obtained in the hyperbaric chamber were presented to 15 member panels in order to obtain the speech intelligibility scores. The volunteer listeners were all young adult Navy personnel selected after passing a 15 dB screening (ISO standards) at the speech frequencies and also after scoring 92 percent on a PB-25 practice list. In all, there were 12 panels of listeners; each panel judged two word lists from two depths and two exercise levels. All lists were presented binaurally through 15 matched sets of TDH-39 earphones which were fed by an Ampex 601 tape recorder. The signal level at the earphones was 74 dB with reference to .0002 dynes/cm^2. The ambient noise produced by the bicycle and the hyperbaric chamber was approximately 15-18 dB below the level of the average speech signal. The listeners were instructed to write the

word spoken by the talker; guessing was encouraged. The mean and standard deviations for each group were obtained. The intelligibility score represents the percent correct for each talker at a particular depth and work load.

RESULTS

Figure 1 presents the mean intelligibility scores at each depth for each power load. From the mean values at the no exercise condition, it can be seen that there is a continued decrease in the intelligibility as the pressure increases. At the surface, intelligibility scores averaged 95 percent with a 2.4 percent standard deviation. The scores dropped to 74 percent at a pressure equivalent to 150 feet of sea water, a drop of 21 percent from the surface level. The remainder of this figure indicates that for the three power loads, intelligibility dropped at each depth upon initiation of exercise; however, the mean intelligibility scores are very similar for all three power loads at any one depth. Thus from these results, it appears that two conditions are contributing to the loss in speech intelligibility: first, a characteristic degradation of speech as a result of increased ambient pressure; and second, an additional drop in intelligibility related to the onset of exercise but apparently not to the degree of the exercise. For the first condition, an analysis of variance produced an F equal to 39.96 ($F_{.05, 3, 60} = 2.76$) indicating that the decrease in intelligibility due to pressure alone was statistically significant at the .05 level. For the second condition, the 3 power loads were grouped and tested against the no exercise condition, and the drop due to the combined exercise loads was statistically significant at each depth except the surface at the .05 level.

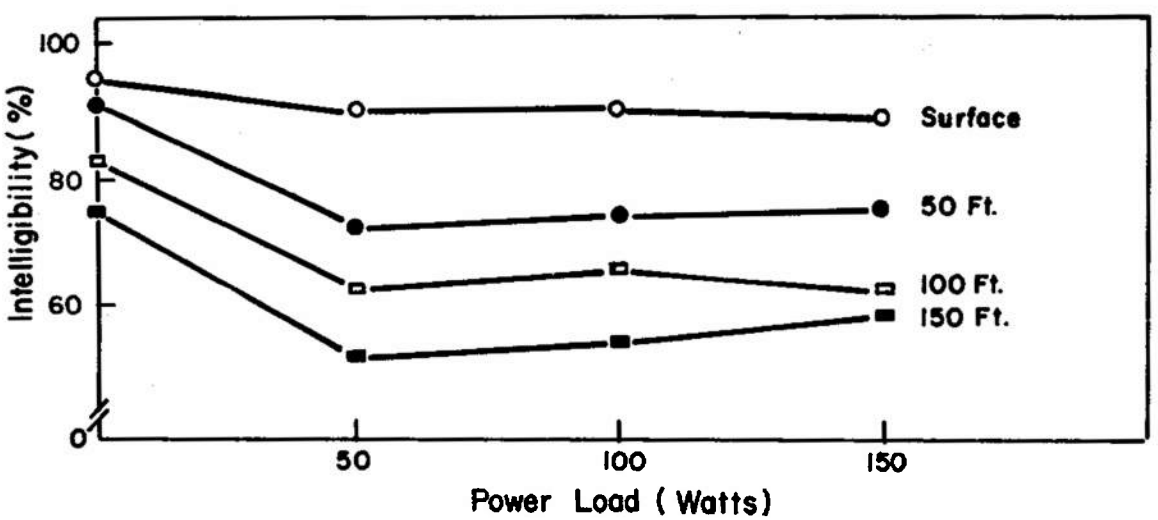

Fig. 1. Mean speech intelligibility scores for all talkers as a function of power load.

In order to look more closely at the effects of exercise, Figure 2 plots the intelligibility as a function of depth. For the surface trial, there was a 6.75 percent drop in mean intelligibility from the no exercise to the highest exercise condition. The major decrease in intelligibility, however, takes place from the no exercise to the 50 watt power load. There is essentially no further drop in the intelligibility scores for the other exercise conditions.

From Figure 2, it can also be seen that for the same amount of exercise, the loss in intelligibility increased slightly as depth increased. That is, the effects due to depth and exercise can both be seen to contribute to the overall degradation of the speech signal. The relative contributions vary primarily as a result of depth once the initial change from rest to exercise takes place.

Figure 3 presents the physiological data and its relationship to intelligibility. On the left side of Figure 3, mean intelligibility is plotted as a function of heart rate; on the right half, mean intelligibility is plotted against mean respiratory rate. In both cases, the solid lines show the power load in watts and the dotted lines indicate the depths. This figure shows that both heart rate and respiratory rate increase for increasing power loads. As depth increases, however, both heart rate and respiratory rate decrease for a given power load. Under the hyperoxic conditions of the dive at the increasing depths, such a result can be expected. Thus, while the physiological effects of exercise were apparent at each depth and each exercise level, the intelligibility remained essentially stable after its initial drop at the 50 watt power load.

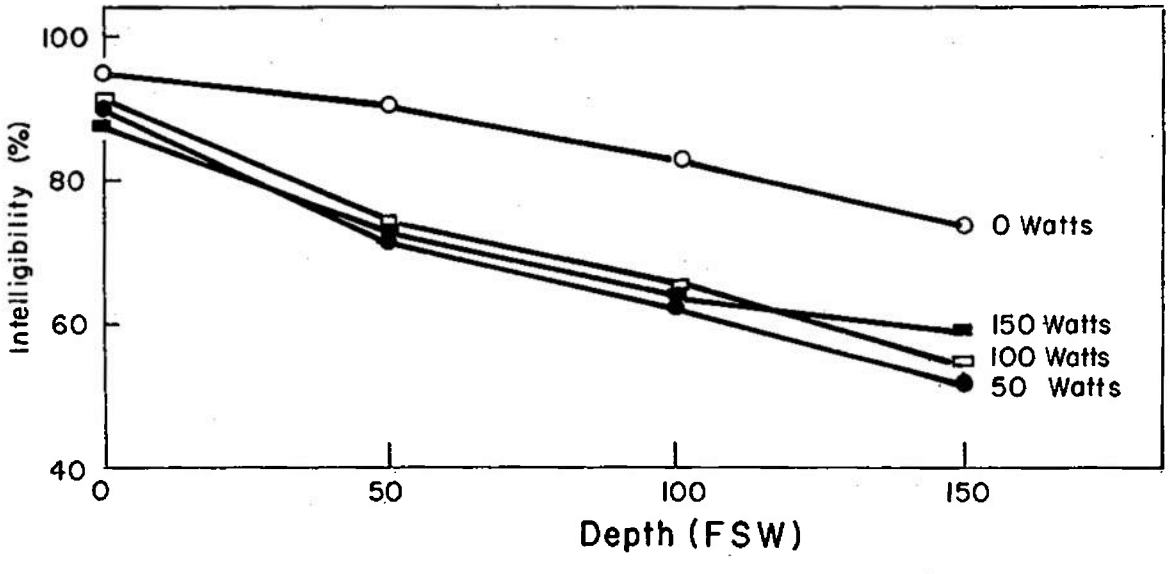

Fig. 2. Mean speech intelligibility scores for all talkers as a function of depth.

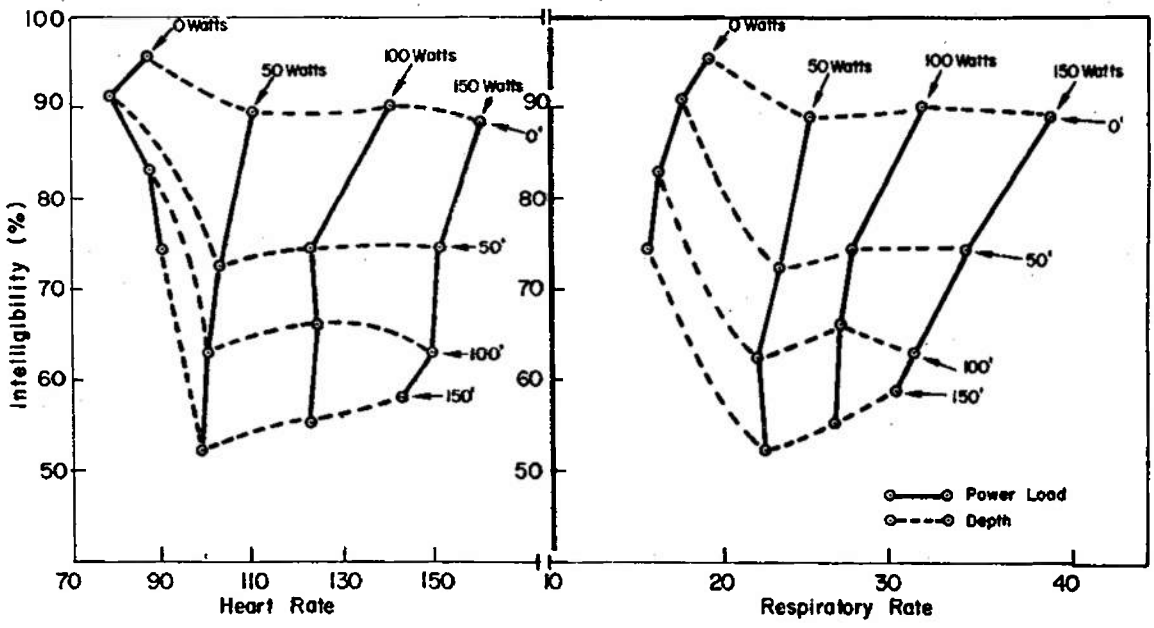

Fig. 3. Mean speech intelligibility scores for all talkers as a function of heart rate (left) and respiratory rate (right). The solid lines indicate the trend for power levels; the dotted lines indicate the trend for depths.

DISCUSSION

The intelligibility results of this study for the no exercise condition agree with previous studies by White[3] and by Hollien[4] who recorded approximately a 20 percent decrease in speech intelligibility from surface to 150 feet. It may be of additional interest to note that for increases in depth at any power load including the no exercise condition, the variation among the talker's scores increased and the rank order of talkers at depth in terms of intelligibility changed from the surface ranks. This suggests that individual differences in talkers' ability to function at depth may not relate to existing data on talker differences for a normal speaking situation.

The main effect of exercise versus no exercise produced a statistically significant loss in speech intelligibility. The intelligibility scores did not continue to decrease, however, as the exercise load increased to 150 watts, a level somewhat below exhaustive exercise for adult males. The initiation of exercise imposed an additional 15 percent average drop in the intelligibility at high ambient pressures while only a 6.75 percent loss in the intelligibility was found at the surface. The finding of no decrease in intelligibility as exercise loads increased beyond the 50 watt level suggests that perhaps physical movement alone was responsible for the decrease in intelligibility or that increased physical activities do not affect the diver's ability to communicate once he adjusts to the diving task. It may also be that the subject's attention was diverted from strictly a communication task to one where communication became an overlayed activity.

The physiological data obtained in this study agrees with previous investigations of exercise in hyperoxic conditions [5, 6, 7, 8]. That is, at one depth, heart rate and respiratory rate increased as exercise increases. As depth is increased, the heart rate and respiratory rate decrease for a constant exercise level. The heart rate patterns obtained in this study agree with previous results [5] and may be attributed to the increased level of oxygen at the depths involved. The respiratory rate patterns may be attributable to the increased resistance on the respiratory system caused by the increased air pressure.

These results suggest a further need to study the diver's ability to communicate while carrying out the functions of a working dive. While communication testing under ideal conditions is necessary to obtain baseline data on systems as well as speaker performance, there also appears to be a need to look at the amount of degradation produced during working conditions when the diver is attending to the primary mission of the dive. This data may represent levels of speech intelligibility found in working dive conditions.

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UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
NAVAL SUBMARINE MEDICAL CENTER
Naval Submarine Medical Research Laboratory

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
SPEECH INTELLIGIBILITY DURING EXERCISE AT NORMAL AND INCREASED ATMOSPHERIC PRESSURES

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Interim Report

5. AUTHOR(S) *(First name, middle initial, last name)*
Thomas Murry
Edward Nelson
Edward W. Swenson

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
9 Feburary 1972	6	8

8a. CONTRACT OR GRANT NO.

b. PROJECT NO. M4306.03-2020DAC5

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
NSMRL Report Number 700

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Naval Submarine Medical Center
Box 600, Naval Submarine Base NLON
Groton, Conn. 06340

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DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0102-014-6600

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Speech Intelligibility						
Diver Communication						
High Pressure Physiology						
Hyperbaric Exercise						
Hyperoxia						